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ASSESSMENT OF ENVIRONMENTAL TOBACCO SMOKE AND RESPIRABLE SUSPENDED PARTICLE EXPOSURES FOR NONSMOKERS IN LISBON BY PERSONAL MONITORING

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One hundred and ninety seven randomly selected nonsmoking subjects collected air samples near their breathing zone by wearing personal monitors for 24-h. The study was centred in Lisbon, Portugal and comprised housewives in one group, primarily for assessing exposures in the home, and office workers in a second group to assess the contribution of the workplace to overall exposure. Samples collected were analysed for respirable suspended particles (RSP), nicotine, 3-ethenylpyridine and environmental tobacco smoke (ETS) particles using ultraviolet absorbance, fluorescence and solanesol measurements. Saliva cotinine analyses were also undertaken to confirm the nonsmoking status of the subjects. A large proportion of the data was below the limit of quantification and, apart from housewives from nonsmoking homes, there were few significant differences noticeable in 24-h time weighted average (TWA) concentrations between subject groups. Based on median TWA concentrations the highest exposed office workers encountered 43 μg m^{-3} RSP, 9.3 μg m^{-3} ETS particles and 0.58 μg m^{-3} nicotine. Overall the workplace contributed the most to nicotine and ETS particle exposure, whereas RSP exposure was higher away from the workplace. Annualised exposure estimates suggest that the most highly exposed subjects would receive approximately 20 cigarette equivalents per annum based upon upper decile levels.

INTRODUCTION

The impact of air pollution on health is under detailed investigation in both Europe and the United States (US). An epidemiological study has commenced in the US to investigate air pollution and its impact in over 80 cities. This National Morbidity and Mortality Air Pollution Study (NMMAPS) is under the control of the Health Effects Institute which is funded by industry and the United States Environmental Protection Agency (USEPA). The NMMAPS study will run over 3 years and one of its objectives will be to compare ambient monitoring data with measurements of personal exposure.

Personal air monitoring was chosen for this study in place of static or ambient measurements in order to represent personal exposures more accurately. The study was carried out in Lisbon, Portugal, during June/July 1995, over a 24-h period. Subjects also self-reported activities using diaries and questionnaires. Saliva samples were taken for cotinine analysis before and after the 24-h period. Environmental tobacco smoke (ETS) particles were measured using ultraviolet absorbing particulate matter (UVPM), fluorescing particulate matter (FPM) and solanesol related particulate matter (SolPM). Nicotine and 3-ethenylpyridine

(3-EP) measurements were also made to assess ETS components in the vapour phase. In order to estimate exposures to ETS and respirable suspended particles (RSP), households and workplaces were classified as smoking or nonsmoking. Other recent studies used similar methodologies (Sterling et al. 1996; Jenkins et al. 1996; Heavner et al. 1996; Baek et al. 1997).

Lisbon was the sixth successive major European city studied by these authors on air quality, following investigations in Stockholm (Phillips et al. 1996), Barcelona (Phillips et al. 1997a), Turin (Phillips et al. 1997b), Paris (Phillips et al. 1998b) and Bremen (Phillips et al. 1998a). The study set out to assess the exposure of housewives and office workers to RSP and ETS particles by obtaining accurate measurements of air concentrations. The information collated here should provide some meaningful data to allow informed and objective debate on issues related to passive smoking and exposures to RSP overall. The main objectives of this study were:

1) To recruit random subjects, who were representative of the population of Lisbon divided into six separate lifestyle "Cells".

2) To determine the range and degree of personal exposure of these Cells of selected subjects to RSP and ETS constituents by means of personal air sampling over a 24-h period.

3) To assess the contribution of the workplace to overall exposure to ETS and RSP.

METHODS

Recruitment of subjects

Recruitment was performed by Cartesius/PDM, a leading direct marketing company in Portugal who possessed the most complete personal database in the country. A random sample of approximately 5000 subjects was selected from the database to be compliant with the following criteria:

1) All subjects to be self-reported nonsmokers living within 15 km of Lisbon city centre.

2) Equal proportions from three age groups 20-34, 35-49, and 50-64.

3) Subjects lifestyles to be representative of the population within 15 km of the city centre.

4) Subjects to be distributed between six "Cells" as indicated in Table 1, Cells 3-6 being targeted at office workers.

Telephone ownership was not very widespread in Lisbon, hence all the subjects were contacted by letter and were asked to telephone Cartesius/PDM if they were willing to participate in an international air quality survey. Telephone respondents were screened to confirm their eligibility to participate in the study and suitable volunteers were given an appointment to attend an information/training session organised at the Hotel Lisboa Plaza in Lisbon.

In order to assign subjects into Cells, as depicted in Table 1, their household was classified as "smoking" if a smoker of cigarettes or pipes/cigars was resident within the household and also normally smoked within communal areas of the household. The smoking status of a workplace was defined by the absence/presence of smoking co-workers within 30 m of the subject's workstation. These definitions were chosen to best represent 'real world' situations and for consistency across the different cities under study, since attitudes of their residents vary considerably from country to country. The regulations governing air quality in the workplace were also different in each country at the time the study was undertaken.

The monitoring session

Subjects were required to wear a personal monitor, designed to collect particulate and vapour phase components present in the air close to the subject's breathing zone (Ogden et al. 1996). RSP and ETS particles were collected onto a Fluoropore membrane filter, nicotine and 3-EP were adsorbed onto XAD-4 resin beads. The personal monitoring methodology has been described in detail elsewhere (Phillips et al. 1996) and consisted briefly of the following:

Initial visit to the study centre: On arrival subjects were shown an instructional video, dubbed into Portuguese, explaining the objectives of the air quality survey. Each was given further instructions regarding use of the equipment and how to complete the documentation by locally recruited interpreters. Subjects were issued Portuguese language questionnaires and diaries for recording exposures and observations over the 24-h collection period and were supervised during completion of a "first visit" questionnaire. In order to avoid misinterpretation and possible errors

Table 1. Cell categorisation by home and workplace status (Lisbon).

Cell	Study type	Smoking status		Planned number
		Household	Workplace	
1	Single monitor	Smoking	-	55
2	Single monitor	Nonsmoking	-	40
3	Dual monitor	Smoking	Smoking	45
4	Dual monitor	Smoking	Nonsmoking	30
5	Dual monitor	Nonsmoking	Smoking	40
6	Dual monitor	Nonsmoking	Nonsmoking	30

translation, all questionnaires and diaries were designed for either numeric or tick-box answers. Nonworking subjects recruited for participation in Cells 1 and 2 were provided with a single personal monitor for use over the collection period (single monitor study). Working subjects recruited for participation in Cells 3 to 6 were provided with two personal monitors for use over the same period (dual monitor study). All subjects were required to provide a saliva sample prior to the monitoring period (pre-sample).

Final visit to the study centre: Following completion of the 24-h monitoring period, subjects returned their personal monitors and associated documentation to the study centre. Subjects also provided a second saliva sample (post-sample) and completed a "last visit" questionnaire.

ANALYTICAL PROCEDURES

All analytical procedures were validated and have been fully described previously by these authors (Phillips et al. 1996). In this study the following analytes were determined:

1) RSP – using a gravimetric procedure (Ogden et al. 1990).

2) Saliva cotinine – using a radioimmunoassay procedure (Van Vunakis et al. 1987; Davis and Stiles 1993).

3) Nicotine and 3-EP – using a capillary gas chromatography (GC) procedure with nitrogen specific detection (Ogden et al. 1989).

4) Estimation of ETS particles (3 procedures) – using high performance liquid chromatography (HPLC) procedures to determine the ultraviolet absorbance (UVPM), fluorescence (FPM) or solanesol content (SolPM) of methanolic filter extracts (Ogden et al. 1990; Phillips et al. 1996). The factors used in this study to convert instrument responses into an equivalent concentration of ETS particles were 49 (SolPM), 47 (FPM) and 8.9 (UVPM) as determined by Nelson et al. (1997).

The analytical limits of quantification (LOQ) for these analyses are presented in Table 2, together with the proportion of data below the LOQ. In order to calculate summary statistics, any data below the analytical LOQ was assigned a value of ½LOQ prior to the calculation of exposure concentration using the appropriate air sampling volume. The LOQs expressed as air concentrations in Table 2 are therefore only an approximation as they varied for each sample dependent upon the sampling pump flow rate and monitoring time.

SUBJECT SELECTION

Of the 245 subjects that were initially recruited for the study, 3 were excluded because they failed to collect their samples correctly, 1 subject was excluded after having admitted to being a smoker during the initial visit to the study centre and 43 subjects were excluded because their saliva cotinine levels were above the selected threshold (25 ng mL^{-1}) for nonsmokers. A further subject was excluded due to the absence of saliva cotinine data required to confirm nonsmoking status.

The age and sex distributions of the remaining 197 subjects who successfully completed the study are presented in Table 3, which shows that the sex distribution was close to the target of 50% per sex in the dual monitor study. However difficulties in recruiting housewives meant that a number of househusbands were recruited for the single-monitor study. There was a considerable over-representation of the youngest age group from the targeted 33% in the dual monitor study (Fig. 1), probably reflecting the age distribution of

Table 2. Limits of quantification (LOQ) for the analytical methods (Lisbon).

Measurement*	Analytical LOQ	LOQ expressed as an air concentration according to sampling time (μg m^{-3})** 24 h	16.10 h[1]	7.63 h[2]	Proportion of data below the LOQ
RSP	38.8 μg/filter	16	23	49	37%
UVPM	1.34 μg/filter	0.54	0.80	1.7	1%
FPM	0.30 μg/filter	0.12	0.18	0.38	1%
SolPM	0.74 μg/filter	0.30	0.44	0.93	63%
Nicotine	0.1 μg/tube	0.09	0.13	0.27	56%
3-Ethenylpyridine	0.1 μg/tube	0.09	0.13	0.27	64%
Saliva cotinine	1.0 ng mL^{-1}	--	--	--	44%

* RSP: Respirable suspended particles; UVPM: Environmental tobacco smoke (ETS) particles estimated by ultraviolet absorption; FPM: ETS particles estimated by fluorescence; and SolPM: ETS particles estimated by solanesol content.

** A flow rate of 1.72 L min^{-1} through the Fluoropore filter was assumed in the LOQ calculation for RSP, UVPM, FPM, and SolPM. The LOQ calculation for nicotine and 3-ethenylpyridine assumed a flow rate of 0.80 L min^{-1} through the XAD-4 tube.

[1] Mean time spent outside the workplace for working subjects in Lisbon.

[2] Mean time spent at work for working subjects in Lisbon.

Table 3. Age and sex distribution for study subjects (Lisbon).

Cell*	Sex		Age range					Overall total
	Males	Females	<20	20 - 34	35 - 49	50 - 64	>64	
1 (SH)	6	18		9	8	7		24
2 (NSH)	17	39	1	16	21	16	2	56
3 (SH, SW)	8	20		18	3	7		28
4 (SH, NSW)	4	3		5	2			7
5 (NSH, SW)	34	27		32	16	13		61
6 (NSH, NSW)	11	10		15	4	2		21
Single monitor total	23	57	1	25	29	23	2	80
Dual monitor total	57	60		70	25	22		117
Overall total	80	117	1	95	54	45	2	197

* SH: smoking household; NSH: nonsmoking household; SW: smoking workplace; NSW: nonsmoking workplace.

office workers in Lisbon. The participants were questioned about their occupation on the last visit questionnaire, and were restricted to a choice of 12 occupations from which to select and provide their answers. The occupations of the 117 subjects who responded to this question are listed in Table 4.

During recruitment it was found that nonsmoking households were more prevalent than smoking households and that smoking was allowed in most office environments. Recruitment of the planned number of subjects into Cells consisting of smoking households (SH) and nonsmoking workplaces (NSW) therefore proved to be unachievable despite extending the recruitment period. To compensate for this shortfall, and to more closely reflect the city's population, Cells consisting of nonsmoking households (NSH) and smoking workplaces (SW) were over-recruited compared with their original planned total.

WEATHER AND POLLUTANT INFORMATION

Detailed information about the weather conditions during the course of the study were obtained from the

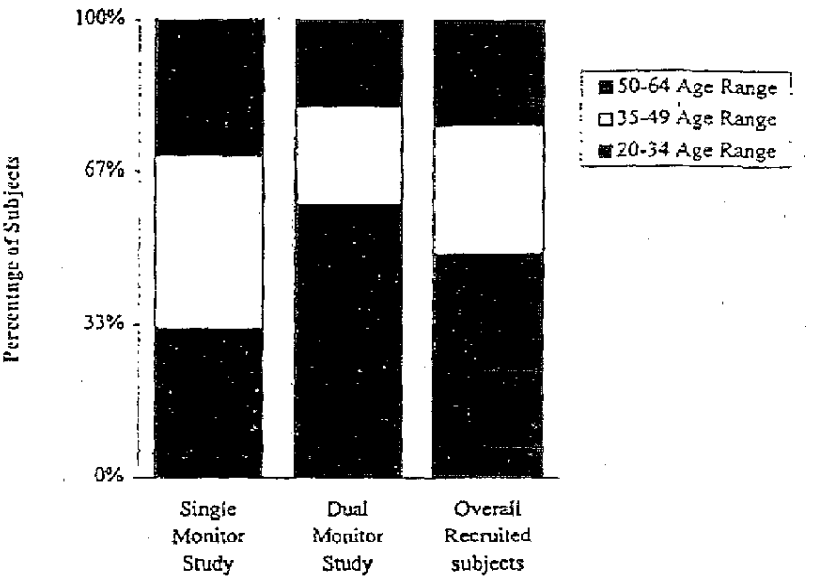

Fig. 1. Age distribution for recruited subjects (Lisbon).

Table 4. Occupations of recruited working subjects (Lisbon).

Occupation	Number of responses
Administration/secretarial	20
Building/construction	3
Education	12
Engineering	4
Government agency (civil service)	9
Legal/financial (e.g., solicitor, banker)	9
Hotel/restaurant/leisure industry	7
Medical (e.g., doctor, nurse)	2
Transportation/haulage	1
Wholesale/retail (e.g., shop assistant)	6
Science/computing	8
Supply industry	3
Other	33
Total	117

Instituto de Meteorologia based at Lisbon airport, and levels of certain pollutants were obtained from Comissão de Gestão do Ar de Lisboa, an organisation responsible for the Lisbon air quality network. The study was carried out between 24th June and 13th July 1995 during which time concentrations of particulates, NO, NO_2, SO_2 and CO were obtained from monitoring stations situated around the Lisbon area. Overall daily mean NO_2 concentrations varied from 37 to 104 $\mu g\,m^{-3}$ and were above 100 $\mu g\ m^{-3}$ on only 1 d of the 20 d study period. The SO_2 concentrations followed a similar trend with daily mean concentrations varying from 3.5 to 37 $\mu g\ m^{-3}$ and were above 10 $\mu g\ m^{-3}$ on only 2 d of the study period. The air quality, based on the United Kingdom bandings and using SO_2 as the descriptor, could therefore be described as very good for the entire study period. Using NO_2 as the descriptor, the air quality fell into the good band for approximately 50% of the time and could be described as poor on only 1 d. Particulate matter concentrations, expressed as daily means, varied from 39 to 90 $\mu g\ m^{-3}$ with an overall average of 52 $\mu g\ m^{-3}$ during the study period. With the exception of Stockholm, the levels of all air pollutants were lower than any other European city studied to date by these authors. Temperatures varied from a minimum 16°C to a maximum of 35°C with daily means between 19°C and 25°C, the overall daily average being 21°C. Relative humidities varied from 30% to 91% (overall average of 68%) and windspeeds of up to 27 km h^{-1}, with an overall average of 12.9 km h^{-1} were recorded.

SMOKING STATUS

Saliva cotinine levels were determined in order to verify that recruited subjects had correctly reported themselves as nonsmokers. Various threshold levels, above which subjects would be classified as smokers,

have been suggested and include 10 ng mL^{-1} (Etzel 1990), 15 ng mL^{-1} (McNeill et al. 1987), 30 ng mL^{-1} (Lee 1987) and more recently 100 ng mL^{-1} (Sterling et al. 1996). In this study 25 ng mL^{-1} (maximum of pre- and post-levels) was chosen as a suitable cut-off level, as used and described previously by these authors (Phillips et al. 1994). Using this threshold, 43 subjects with levels between 33.7 and 987 ng mL^{-1} were assumed to be smokers and were excluded from the study. A further subject was excluded from the study after admitting to being a smoker on the first visit questionnaire, although measured pre- and post- saliva cotinine levels for this subject were 1.07 and 0.5 ng mL^{-1} respectively, not indicative of a regular smoker. This possibly suggests that the subject abstained from smoking for several days before the study started, was a light smoker or non-inhaler ("mouth-puffer"), had misreported their smoking status, or inefficiently metabolised nicotine to cotinine. This latter phenomenon has received some recent attention in the literature and was summarised by Ogden et al. (1997a).

In this study subjects were required to confirm they had been nonsmokers for more than six months and no attempt was made to differentiate between "non" and "never" smokers. Various criteria can be used to assess the rate at which recruited subjects misreport their smoking status, including responses to questionnaires. Depending upon the criteria used, the rate at which subjects misclassified their smoking status in this study ranged between 17.9% (43 from 240) and 18.3% (44 from 241). These misclassification rates were slightly higher than those found by these authors in Barcelona and were the highest rates observed in the European cities studied to date (Table 5). However, since telephone ownership in Lisbon was low, the initial contact for the recruitment of subjects was made by letter, which mentioned the payment of a gratuity to participants. The high numbers of subjects misreporting their smoking status may have responded as they did due to the mention of this gratuity. The use of a letter without the mention of a gratuity was abandoned due to the extremely poor response rate achieved.

Etzel's review (1990) of the use of saliva cotinine for this purpose suggests that subjects with cotinine levels between 10 and 100 ng mL^{-1} may be classified as infrequent smokers, and had 10 ng mL^{-1} been selected as the cut-off level a further 3 subjects would have been rejected. Delfino et al. (1993) rejected only 3 out of 251 subjects using a cut-off of 20 ng mL^{-1}, whereas Sterling et al. (1996) could have rejected 2 out of 25 had they used a similar threshold level instead of 100 ng mL^{-1}. In a study of cardiovascular risk factors in 5115 young adults (CARDIA) Wagenknecht et al. (1992) found a misclassification rate of 4.2% based on a serum cotinine cut-off of 14 ng mL^{-1}. It is interesting to note that they classified nonsmokers as subjects having reported smoking less than 5 cigarettes per week for the previous 3 months. An exclusion rate of 4.2%, using a 15 ng mL^{-1} saliva discrimination level, was also found on a recent personal air monitoring study (Jenkins et al. 1996) of 1564 subjects in the United States. In a nationally representative study of married females in the US, Ogden et al. (1997a) found misclassification rates among self-reported never smokers of 5.3%, 3.5% and 2.5% using saliva discrimination levels of 10, 35 and 106 ng mL^{-1} respectively. Among self-reported nonsmokers (never smokers + former smokers), misclassification rates of 9.2%, 6.4% and 4.7% were found at the same respective saliva cotinine discrimination levels.

Table 5. Misclassification rates of nonsmoking status in European cities.

City	Rate 1*	Rate 2**
Stockholm	2.7%	5.3%
Barcelona	10.5%	17.8%
Turin	1.6%	6.5%
Paris	1.8%	4.7%
Bremen	2.6%	2.6%
Lisbon	17.9%	18.3%

* Rate 1: The percentage of self-reported (first visit questionnaire) nonsmokers with a saliva cotinine level in excess of 25 ng mL^{-1}.

** Rate 2: As Rate 1, with the addition of self-reported (telephone screening) nonsmokers who subsequently reported themselves as smokers on the first visit questionnaire.

RESULTS AND DISCUSSION

In order to assign a subject to a particular Cell procedures must be defined to classify the household and/or workplace as smoking or nonsmoking. In a recent US study, using a similar protocol to these European studies, Jenkins et al. (1996) reported data based on two separate procedures. Initially subjects were assigned to a Cell based upon their responses to the telephone screening questionnaire, Cell categorisations were subsequently refined by rejection of subjects

Table 6. Correlation coefficients for ETS markers (Lisbon).

"Y" data	vs.	"X" data	Data pairs	R-squared	Gradient	Intercept
FPM		UVPM	307	0.699	0.669	-0.24
SolPM		UVPM	307	0.476	0.703	-2.58
SolPM		FPM	314	0.787	1.044	-2.44
3-EP		Nicotine	305	0.792	0.309	0.13
FPM		Nicotine	305	0.421	6.186	4.25
SolPM		Nicotine	305	0.418	7.367	1.39
UVPM		Nicotine	299	0.376	6.402	7.93
SolPM		3-EP	305	0.524	23.74	-1.68
FPM		3-EP	305	0.597	21.22	1.13
Post-cotinine		Nicotine*	179	0.167	0.631	1.13
Post-cotinine		SolPM*	187	0.038	0.021	1.40
Post-cotinine		FPM*	187	0.048	0.030	1.30

* Time-weighted average (TWA) concentrations correlated for working subjects (Cells 3 to 6).

Table 7. Correlation coefficients for ETS markers using only data greater than the LOQ (Lisbon).

"Y" data	vs.	"X" data	Data pairs	R-squared	Gradient	Intercept
FPM		UVPM	301	0.698	0.668	-0.22
SolPM		UVPM	110	0.500	0.858	-3.81
SolPM		FPM	116	0.836	1.149	-3.47
3-EP		Nicotine	104	0.769	0.280	0.31
FPM		Nicotine	134	0.347	5.513	8.35
SolPM		Nicotine	86	0.393	7.965	5.31
UVPM		Nicotine	129	0.311	5.127	13.8
SolPM		3-EP	78	0.486	26.70	-3.76
FPM		3-EP	108	0.498	20.75	2.16
Post-cotinine		Nicotine*	40	0.148	0.396	2.130
Post-cotinine		SolPM*	30	0.006	-0.004	2.870
Post-cotinine		FPM*	100	0.003	0.006	2.332

* TWA concentrations used for working subjects (Cells 3 to 6) having results from both the "workplace" and "outside of the workplace" monitors greater than the LOQ.

whose diary observations did not correspond with their initial Cell assignments.

In this study neither of the above procedures were utilised. Instead, Cells were categorised according to the answers provided on the first visit questionnaire. It was believed that responses to the screening questionnaire could not always be guaranteed due to variations in translations and the possible incorrect categorisation of Cells by telephonists working for the recruitment agencies. It was noted on the pump survey questionnaires that 47% of the subjects admitted to incomplete recording of diary information and using diary observations to refine Cell categorisation was not performed in this instance. The use of diary information for this purpose is regarded as a subject for future consideration.

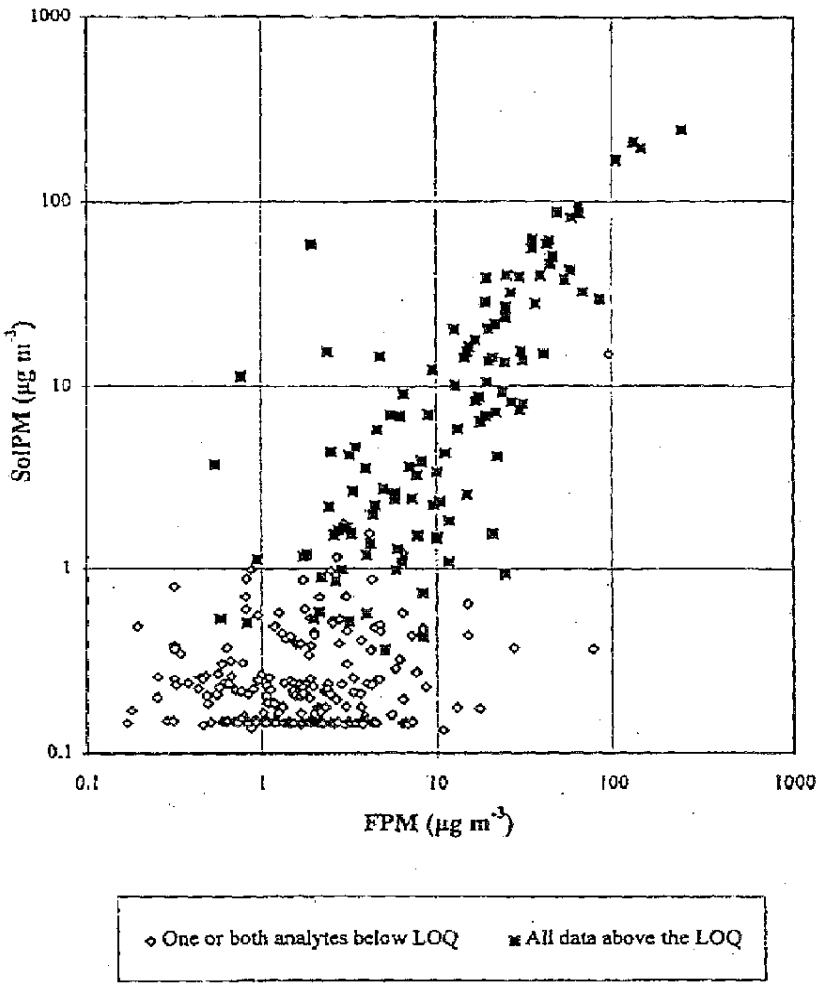

Fig. 2. Correlation of SolPM with FPM (Lisbon).

Comparison of markers for estimating ETS concentrations

Table 6 lists the correlation and best fit line coefficients between various analytes measured in this study. The same information is listed in Table 7 after removal of data pairs where either analyte was below the LOQ. The correlations between SolPM, FPM and nicotine are also depicted as scatter diagrams (Figs. 2 - 4), and the cumulative frequency distributions for all the analytes are presented in Figs. 5 and 6.

Examination of Tables 6 and 7 shows good correlation between ETS particle estimates using SolPM and FPM methods ($R^2 = 0.836$), and moderate correlation between UVPM and SolPM/FPM estimates. The gradient of best fit lines suggests the expected overall trend of UVPM>FPM>SolPM, an observation confirmed by Fig. 5, however an indication that SolPM may give higher estimates for ETS particles than FPM above approximately 20 $\mu g\ m^{-3}$ is apparent. These higher estimates of ETS particle concentrations using SolPM, compared with FPM, are also evident in Fig. 2 at higher levels. Throughout this publication ETS particle concentrations, corresponding cigarette equivalent (CE) calculations and comparisons between subject groups and Cells were based upon both FPM and SolPM determinations. It has been suggested previously (Ogden et al. 1990) that SolPM, and to some extent FPM, methods are more specific to ETS particles than the use of UVPM methods which will be sensitive to other combustion sources.

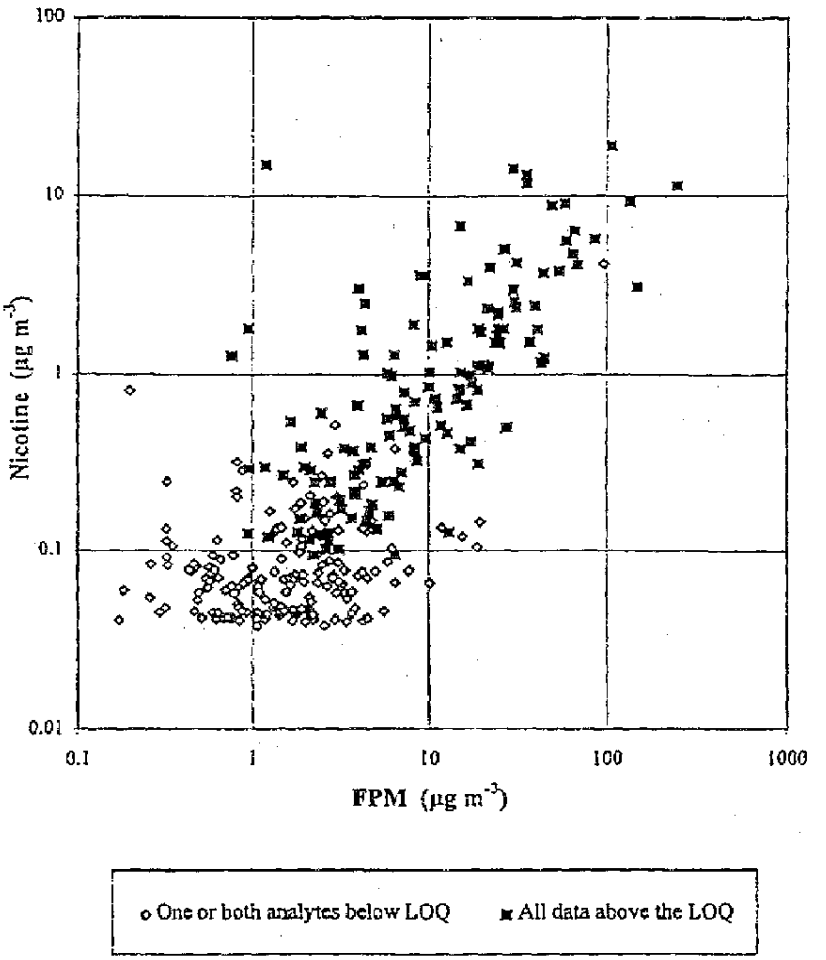

Fig. 3. Correlation of FPM with nicotine (Lisbon).

Visual inspection of the correlations of SolPM and FPM against nicotine (Figs. 3 and 4) would suggest that FPM correlates better than SolPM, however this was not confirmed by the R^2 values in Table 7 possibly due to outlying data pairs. Determined nicotine and 3-EP concentrations showed fairly good correlation, with a gradient suggesting that nicotine concentrations were approximately three times higher than 3-EP. There was also an indication in Table 7 that ETS particle concentrations correlated better with 3-EP than nicotine, however the majority of data for both vapour phase components were below the LOQ (Table 2). These results indicate that 3-EP may have a future role as an ETS marker, particularly if the LOQ could be improved.

There were poor correlations for post-cotinine concentrations with both vapour and particulate phase ETS measurements. These poor correlations may be due to the large proportion of results being close to or below the LOQ, where acceptable assay reliability is at a minimum. These findings reinforce the belief that cotinine measurements, using the current LOQ, are not a reliable marker for ETS exposure.

The range and number of data points below the LOQ, particularly for SolPM and nicotine, are evident in Figs. 2 - 4. These data also manifest themselves as "plateaux" on the cumulative distribution curves (Figs. 5 and 6). A considerably higher proportion of SolPM results were below the LOQ compared with either UVPM or FPM (Table 2). This is to be expected

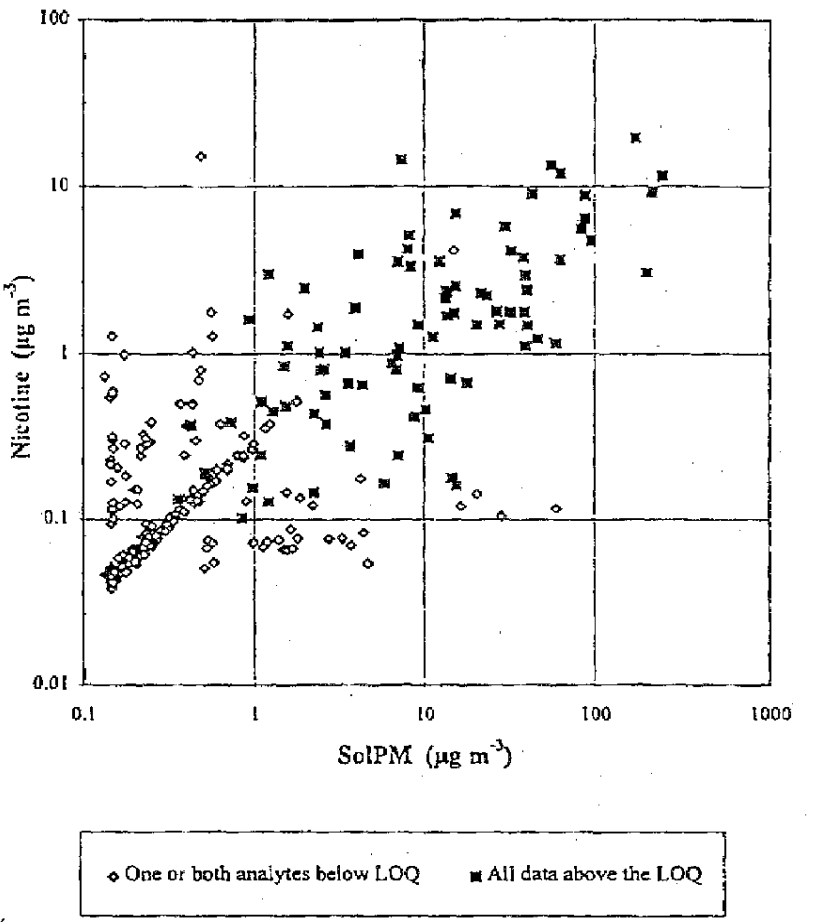

Fig. 4. Correlation of SolPM with nicotine (Lisbon).

based upon the assumption that SolPM is more tobacco specific than either UVPM or FPM. Additionally, of the SolPM estimates below the LOQ, more than 25% and 16% of corresponding nicotine and 3-EP concentrations, respectively, were quantifiable.

In this study, ETS particle estimates using SolPM, FPM, and UVPM produced a number of values (7, 5 and 10 respectively) that were higher than the corresponding RSP measures, the majority of these anomalous results occurred where the RSP concentration was below the LOQ. As discussed previously (Phillips et al. 1996), the analytical LOQ for RSP was calculated as the mean plus two standard deviations (SD) of the weight changes observed for filter blanks. The SD observed in this study was the highest observed by these authors in the European cities studied to date. The reasons for that are not clear, resulting in an analytical LOQ of 38.8 μg per filter.

Concentrations of ETS constituents to which Lisbon subjects were exposed

In this publication, median values were primarily used for reporting RSP and ETS marker concentrations since the data generated were highly skewed. Previously these authors have suggested that geometric means (Phillips et al. 1998b) or 90th percentile values (Phillips et al. 1998a) may provide more appropriate statistics for ranking or comparing Cells. All of these summary statistics, together with arithmetic means and 10th percentile (lower decile) values were reported for each data set.

Particulate and vapour phase components measured for housewives/househusbands were compared, by Cell, with calculated time weighted average (TWA) concentrations for individual workers. These calculations were based on measured concentrations and the operational time over which the monitors were used

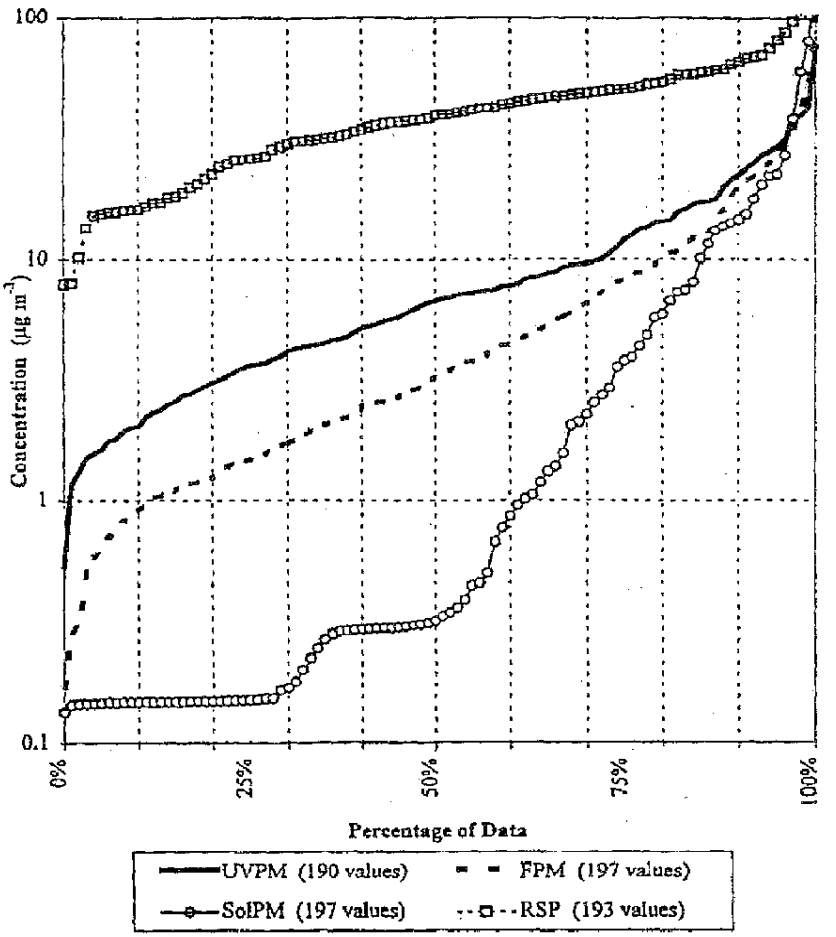

Fig. 5. Cumulative frequency distributions of 24-h TWA particulate matter concentrations (Lisbon).

inside and outside the workplace. These data are summarised in Tables 8 and 9, with corresponding cumulative frequency distributions for ETS particles and nicotine shown in Figs. 7 to 9. The significance of any concentration differences between Cells was examined using the Wilcoxon rank sum test. Prior to the application of this nonparametric test, Kruskal-Wallis nonparametric analysis of variance (ANOVA) was applied to the data in order to detect if there was an overall difference between the Cells. For RSP the overall Kruskal-Wallis analysis proved nonsignificant ($p>0.05$), thus the Wilcoxon rank sum test was not performed as there would have been the possibility of false positives. For all the other analytes investigated, the Kruskal-Wallis ANOVA provided evidence of a significant overall difference between Cells and subsequent pairwise comparisons of Cells were performed using the Wilcoxon rank sum test (Table 10).

The various statistics reported for RSP levels (Table 8) showed few differences between Cells, thus confirming the Kruskal-Wallis analysis. The typical median values of approximately 40 $\mu g\ m^{-3}$ were double those found for subjects in most environments in both Stockholm (Phillips et al. 1996) and the recent 16 city US study (Jenkins et al 1996). The levels for RSP found in this study were comparable with those recorded in Barcelona (Phillips et al. 1996) by subjects within smoking environments. The lack of discrimination between RSP levels for subjects from different environments may be due to good ventilation systems and the fact that the overall average outdoor particle concentrations were relatively low at 52 $\mu g\ m^{-3}$ during the study. Further data analysis, correlating the daily RSP data in this study with the background particulate levels found by the Lisbon air quality network were not attempted.

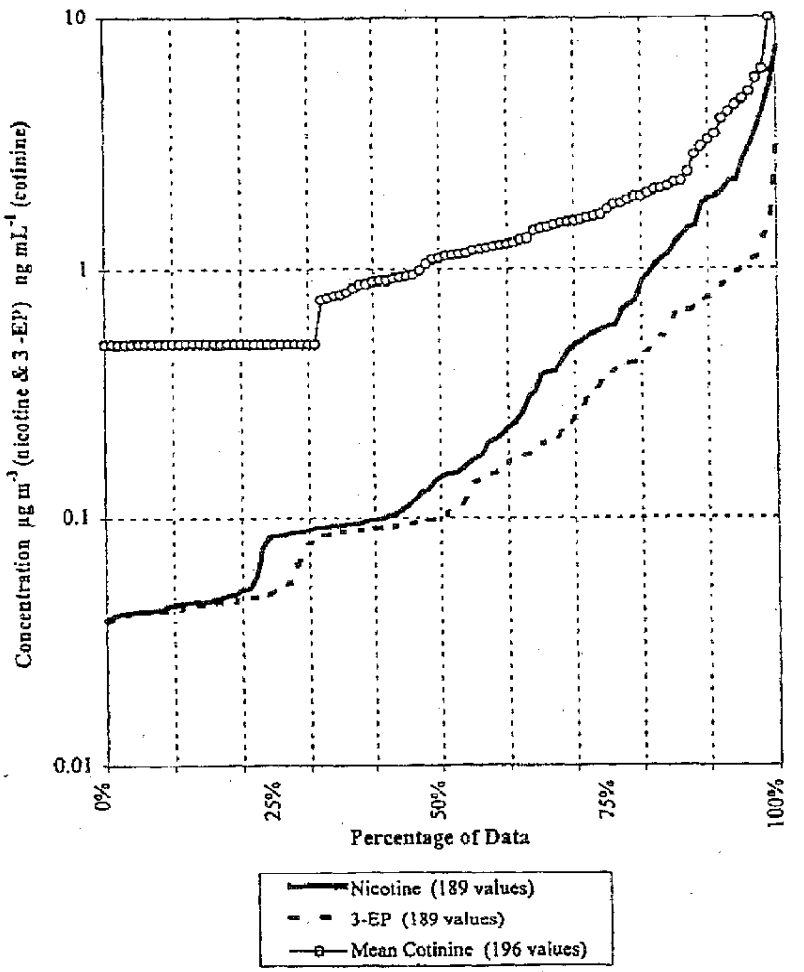

Fig. 6. Cumulative frequency distributions of nicotine, 3-EP, and continine (Lisbon).

It was expected that the highest levels for all ETS markers would be found for either Cell 1 (SH) or Cell 3 (SH, SW), however the highest median levels for all analytes was found for Cell 4 (SH, NSW). These apparently anomalous results were probably due to the low numbers recruited into this Cell and were treated as insignificant. SolPM and 3-EP concentrations for Cell 4 were significantly different ($p < 0.05$) from those for Cell 1 (SH), these differences were disregarded due to the number of data below the LOQ and the different LOQs in the two Cells, as described previously (Phillips et al. 1998a). There were no other significant differences ($p > 0.05$) between Cell 4 concentrations and those for any other Cells consisting of subjects from smoking households or smoking workplaces.

If data below the LOQ is ignored, then for all ETS markers there were few significant differences between Cells evident in either Table 10 or the cumulative distribution curves (Figs. 7 to 9). The only Cell consistently different from all others was Cell 2, housewives from nonsmoking households. The summary statistics for all ETS markers for Cell 2 were lower than those in Cell 6, workers from nonsmoking households and nonsmoking workplaces, possibly suggesting an indistinct segregation of smoking/nonsmoking workplaces. Another possible explanation for this finding may be the fact that since housewives did not have to go out during the monitoring period, they may have elected not to, considering the inconvenience of wearing the sampling pump. Hence sources of

Table 8. Summary statistics for 24-h TWA particle concentrations for all subjects (Lisbon).

Analyte	Cell[a]	Number of subjects	10th percentile	90th percentile	Arithmetic mean	Geometric mean	Median
	1 (SH)	22	20	67	40	35	38
	2 (NSH)	56	19	54	38	34	38
RSP	3 (SH, SW)	28	17	69	45	40	41
($\mu g\ m^{-3}$)	4 (SH, NSW)	7	16	54	38	34	43
	5 (NSH, SW)	61	16	86	47	38	40
	6 (NSH, NSW)	20	16	48	34	31	34
	1 (SH)	24	0.15	13	4.7	0.49	0.16
	2 (NSH)	56	0.15	0.38	0.41	0.20	0.15
SolPM	3 (SH, SW)	28	0.29	24	13	3.2	3.8
($\mu g\ m^{-3}$)	4 (SH, NSW)	7	1.4	14	7.6	4.6	7.5
	5 (NSH, SW)	61	0.30	22	8.4	2.0	1.4
	6 (NSH, NSW)	21	0.29	3.7	1.4	0.59	0.31
	1 (SH)	24	1.1	21	7.7	4.1	3.8
	2 (NSH)	56	0.63	4.8	2.5	1.7	1.7
FPM	3 (SH, SW)	28	1.5	23	14	7.1	6.9
($\mu g\ m^{-3}$)	4 (SH, NSW)	7	2.4	17	9.6	6.9	9.3
	5 (NSH, SW)	61	1.1	25	9.8	4.8	4.2
	6 (NSH, NSW)	21	1.2	11	5.6	3.2	2.1
	1 (SH)	24	2.2	32	13	7.8	8.0
	2 (NSH)	56	1.8	10	5.4	4.2	4.5
UVPM	3 (SH, SW)	26	5.2	29	14	11	9.7
($\mu g\ m^{-3}$)	4 (SH, NSW)	6	5.2	18	12	9.7	11
	5 (NSH, SW)	57	2.7	25	11	7.4	7.8
	6 (NSH, NSW)	21	3.4	16	8.3	6.4	6.8

[a] SH: smoking household; NSH: nonsmoking household; SW: smoking workplace; NSW: nonsmoking workplace.
TWA exposure concentrations, determined for each subject from measured levels both inside and outside the workplace, were used to calculate the above statistical parameters for Cells 3 to 6.

ETS exposure outside the home, travelling for example, would have been avoided.

Median levels of ETS particles found for subjects in Cell 3 (SH, SW) in this study were similar to those found by Jenkins et al. (1996) in a similarly defined Cell in their US study (3.8 vs. 3.76 $\mu g\ m^{-3}$ for SolPM and 6.9 vs 8.64 $\mu g\ m^{-3}$ for FPM). Measured TWA concentrations in all other Cells for working subjects were considerably higher in Lisbon than those found in the US, by factors of between 3.3 and 15 for SolPM and between 2.4 and 3.2 for FPM.

Exposures to RSP, ETS particles and nicotine

The term exposure is often used when defining maximum allowable concentrations for hazardous compounds, and is normally determined by fixed site monitoring over standard time periods. In the context of this personal monitoring study, where concentrations cannot be directly related to a specific environment, the term exposure is used as a measure of overall exposure or potential inhaled quantity and was calculated as the product of the analyte concentration, the length of time subjected to such concentration and the breathing rate maintained throughout the period. A similar assumption was recently made by Ogden and Martin (1997b) who noted that this provided "a more accurate accounting of total exposure among individuals as they engage in different activities in different microenvironments". Where exposures were quoted in terms of CE, these were calculated in relation to the

Table 9. Summary statistics for cotinine and 24-h TWA nicotine and 3-EP concentrations for all subjects (Lisbon).

Analyte	Cell[a]	Number of subjects	10th percentile	90th percentile	Arithmetic mean	Geometric mean	Median
Nicotine ($\mu g\ m^{-3}$)	1 (SH)	24	0.05	1.2	0.59	0.24	0.19
	2 (NSH)	53	0.04	0.31	0.14	0.07	0.05
	3 (SH, SW)	27	0.10	2.8	1.2	0.55	0.58
	4 (SH, NSW)	7	0.13	2.1	0.88	0.46	0.50
	5 (NSH, SW)	58	0.09	2.1	0.84	0.37	0.32
	6 (NSH, NSW)	20	0.09	0.83	0.37	0.16	0.09
3-EP ($\mu g\ m^{-3}$)	1 (SH)	24	0.04	0.39	0.19	0.11	0.11
	2 (NSH)	53	0.04	0.20	0.09	0.06	0.05
	3 (SH, SW)	27	0.09	1.4	0.58	0.33	0.36
	4 (SH, NSW)	7	0.08	0.67	0.39	0.29	0.40
	5 (NSH, SW)	58	0.08	0.91	0.38	0.25	0.20
	6 (NSH, NSW)	20	0.09	0.42	0.18	0.13	0.09
Cotinine[b] ($ng\ mL^{-1}$)	1 (SH)	24	0.50	4.2	1.8	1.4	1.2
	2 (NSH)	55	0.50	2.8	1.4	0.90	0.50
	3 (SH, SW)	28	0.76	3.9	2.1	1.6	1.5
	4 (SH, NSW)	7	0.75	2.8	1.7	1.4	1.8
	5 (NSH, SW)	61	0.50	2.2	1.5	1.1	1.2
	6 (NSH, NSW)	21	0.50	2.2	1.2	0.97	0.81

3-EP = 3-Ethenylpyridine.

[b] Values calculated from the average of pre- and post-monitoring saliva cotinine concentrations.

[a] SH: smoking household; NSH: nonsmoking household; SW: smoking workplace; NSW: nonsmoking workplace.

TWA exposure concentrations, determined for each subject from measured levels both inside and outside the workplace, were used to calculate the above vapour phase statistical parameters for Cells 3 to 6.

mainstream particle (tar) and nicotine yields of typical Portuguese cigarettes, although it is recognised that the particle phases of ETS and mainstream smoke differ considerably in composition and particle size. The values, 11 mg ETS particles and 0.8 mg nicotine, were calculated from the mean yields of the top six selling cigarette brand-types in Portugal. In this publication CEs are used solely for conceptual comparison of exposures between groups of nonsmokers.

Daily exposures, in terms of potential inhaled amounts (μg), calculated for each Cell over the 24-h monitoring period, are summarised in Table 11. A breathing rate of 0.65 $m^3\ h^{-1}$, the average level of respiration calculated for awake females, was used for calculating housewife exposures in Cells 1 and 2. For Cells 3 to 6, where exposures were not sex dependent a breathing rate of 0.85 $m^3\ h^{-1}$ was used, this being an average of the breathing rates for awake males (1.05 $m^3\ h^{-1}$) and females (0.65 $m^3\ h^{-1}$) as reported by Holcomb (1993). A comparable average breathing rate of 0.93 $m^3\ h^{-1}$ was recently used by Jenkins et al. (1996) to estimate exposures in a 16 city US study using similar personal monitoring methods. In this publication both median and 90th percentile values were calculated in order to represent typical and highly exposed subjects, respectively.

In order to estimate annual exposures, separate procedures were adopted for housewives and for workers. The daily exposures calculated for housewives were multiplied by 365 to obtain an estimate of annual exposure. For Cells 3 - 6 (workers) the median and 90th percentile levels were calculated from data provided by the separate monitors worn in the workplace and away from the workplace. Working subjects were assumed to have a breathing rate of 0.85 $m^3\ h^{-1}$ at all times and to spend 35 h per week and 48 weeks per year in the workplace with the rest of the time spent outside the workplace. Annual exposure calculations for all subjects assumed no variation in ETS marker concentrations throughout the year, including week-

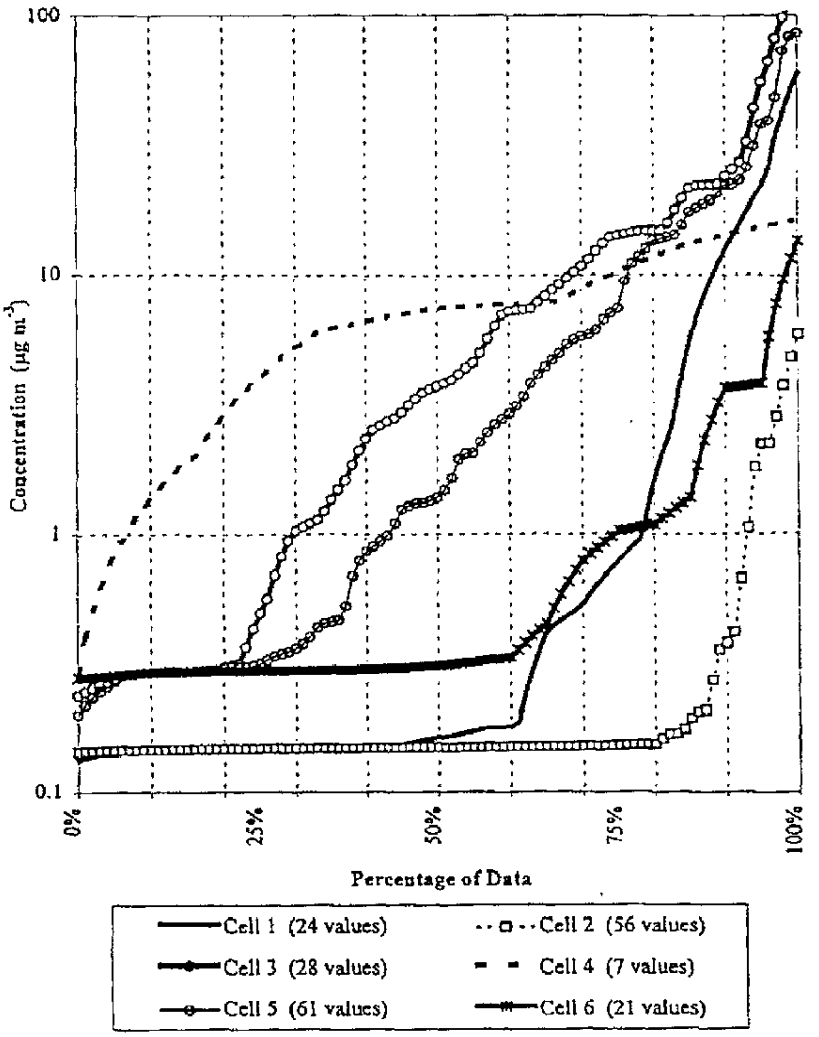

Fig. 7. Cumulative frequency distributions for SolPM by Cell (Lisbon).

ends, from those measured during the monitoring period. Estimated annual exposures using the above assumptions and the median and upper decile concentrations are reported in Table 12, together with estimates for ETS and nicotine exposures in terms of CE.

From Table 11 the highest daily exposure to RSP, ETS particles and nicotine were for workers living in smoking environments. The least exposed subjects over the 24-h period for all analytes were housewives from nonsmoking households.

If the exposures are annualised (Table 12) then ranking Cells by median for nicotine concentrations shows Cell 3 (SH, SW) > 4 (SH, NSW) > 5 (NSH, SW) > 1 (SH) > 6 (NSH, NSW) > 2 (NSH). A similar trend is evident for ETS particles and RSP with Cell 3, workers from smoking households and smoking workplaces, being the most highly exposed and Cell 2, housewives from nonsmoking households, being the least exposed. Annualised exposures to ETS particles, RSP and nicotine for workers appear to be greater than for housewives, although the differing breathing rates assumed for housewives and workers may be a confounder. It is perhaps surprising that housewives from smoking households appear to be less exposed to ETS, based on either median or upper decile amounts, than workers from nonsmoking households and smoking workplaces. This also would suggest that a smoking workplace in Lisbon is a more significant contributor to annual exposure than is a smoking household in Lisbon.

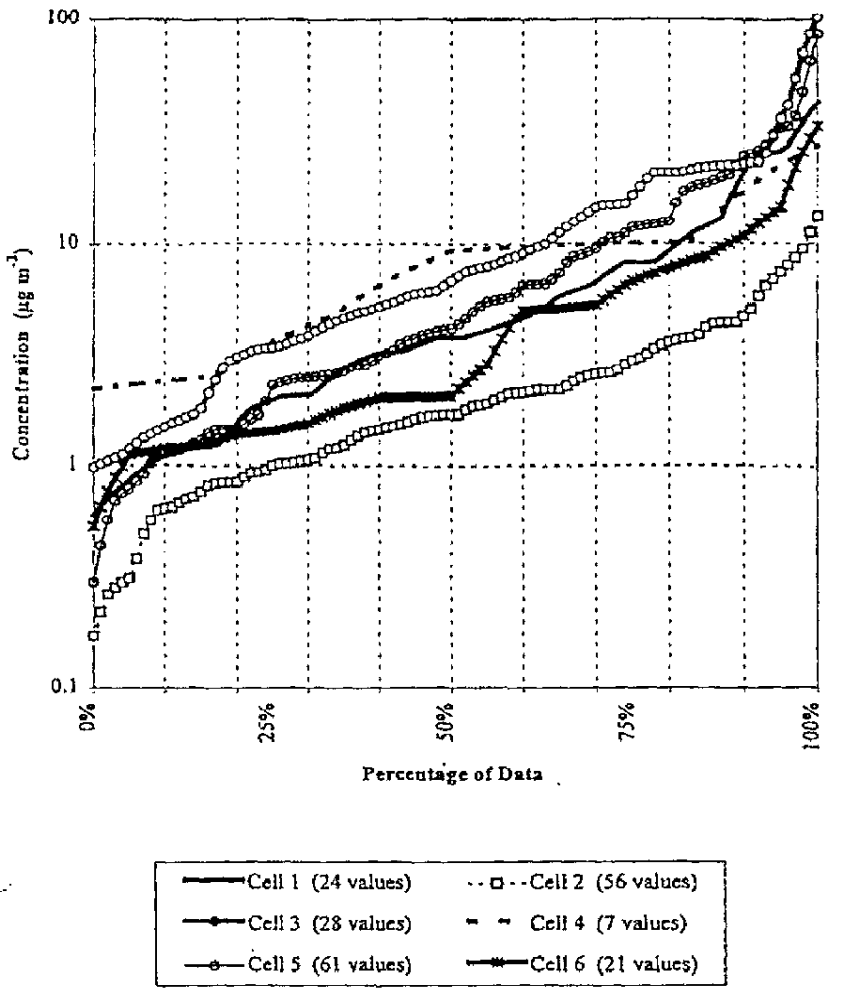

Fig. 8. Cumulative frequency distributions for FPM by Cell (Lisbon).

It is evident from Table 12 that exposures in this study were fairly low, with no group being exposed to more than 4 CE per annum, based upon median levels. The most highly exposed (90th percentile levels) nonsmokers in this study who both worked and lived with smokers would be exposed to less than 26 CE per annum. Conversely, if they came from nonsmoking households/workplaces they would be exposed to less than 3 CE per annum.

It was also possible, by applying the same criteria used for the calculations in Table 12, to estimate the contribution of the workplace to overall annual exposure. These estimates, expressed as a percentage of both median and upper decile results, are summarised in Table 13 and show workplace contributions of up to 90%. If the results from the individual monitors for all workers are pooled, the workplace contributes between 50% and 67% of annual exposure to both ETS particles and nicotine, irrespective of whether median or upper decile levels are used in the calculation.

The exposure estimates reported in Tables 11 to 13 were all calculated using the median/90th percentile levels found in each Cell, together with a single value estimating the breathing rate within the Cell. These assumptions were used previously by these authors and allow direct comparisons between cities studied to date. In this study Cells 1 and 2 did not consist solely of females, hence the validity of the assumptions was investigated using an alternative procedure for exposure assessment. The annual exposures were calculated for each subject using the concentrations determined for their individual monitors and a breathing

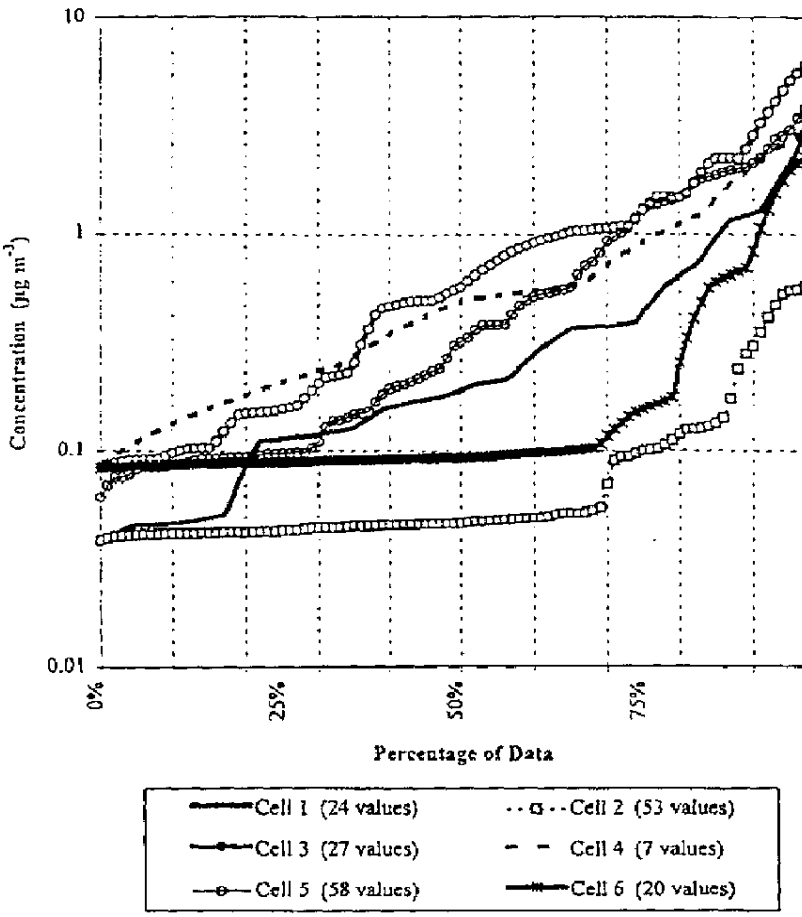

Fig. 9. Cumulative frequency distributions for nicotine by Cell (Lisbon).

rate of 0.65 $m^3 h^{-1}$ for females or 1.05 $m^3 h^{-1}$ for males, and median/90th percentile data subsequently calculated. For housewives (Cells 1 and 2) these median and 90th percentile values derived from individual exposures (Table 14) showed good agreement with those calculated on an overall Cell basis, with relative differences of less than 23% in all cases. Similar variations of up to 30% were evident between the two approaches when workers (Cells 3 to 5) were investigated, with the exception of median SolPM exposures, which were up to three times higher when calculated on an individual basis. These observations highlight the difficulties in estimating exposures by assigning typical exposure levels to subjects in multiple environments, particularly when the data distributions in each environment are highly skewed. Improved analytical LOQs, particularly for SolPM determinations, or increased sampling times would decrease the percentage of data below the LOQ and decrease the differences in exposure assessments between the two procedures.

This individual approach was extended to provide an alternative estimation of the percentage contribution of the workplace to overall exposures by calculating the median and 90th percentile of contributions determined for each individual. These were compared with the original estimates in Table 13 which reported contributions based upon median and upper decile concentrations. For this comparison the median contributions were similar to those reported in Table 13, suggesting the validity of either approach. However at higher levels, the calculations based on individually derived data reported much higher contributions. At the 90th percentile for all workers, annual workplace exposure contributions of 65% for RSP, 92% for nicotine and 98% / 91% (SolPM/FPM, respectively)

Table 10. Significance of differences in ETS marker concentrations between Cells based upon Kruskal-Wallis ANOVA and subsequent Wilcoxon rank sum test (Lisbon).

SolPM		Cell 3	Cell 4	Cell 1	Cell 5	Cell 6	Cell 2
	Median	3.8	7.5	0.16	1.4	0.31	0.15
vs. Cell 3	3.8	--					
vs. Cell 4	7.5	NS	--				
vs. Cell 1	0.16	☆☆☆	☆	--			
vs. Cell 5	1.4	NS	NS	☆☆☆	--		
vs. Cell 6	0.31	☆☆	☆☆	☆	☆☆	--	
vs. Cell 2	0.15	☆☆☆	☆☆☆	☆	☆☆☆	☆☆☆	--

FPM		Cell 3	Cell 4	Cell 1	Cell 5	Cell 6	Cell 2
	Median	6.9	9.3	3.8	4.2	2.1	1.7
vs. Cell 3	6.9	--					
vs. Cell 4	9.3	NS	--				
vs. Cell 1	3.8	NS	NS	--			
vs. Cell 5	4.2	NS	NS	NS	--		
vs. Cell 6	2.1	☆	NS	NS	NS	--	
vs. Cell 2	1.7	☆☆☆	☆☆	☆☆	☆☆	☆	--

Nicotine		Cell 3	Cell 4	Cell 1	Cell 5	Cell 6	Cell 2
	Median	0.58	0.5	0.19	0.32	0.09	0.05
vs. Cell 3	0.58	--					
vs. Cell 4	0.5	NS	--				
vs. Cell 1	0.19	☆	NS	--			
vs. Cell 5	0.32	NS	NS	NS	--		
vs. Cell 6	0.09	☆☆☆	NS	NS	☆☆	--	
vs. Cell 2	0.05	☆☆☆	☆☆☆	☆☆☆	☆☆☆	☆☆☆	--

Cotinine		Cell 3	Cell 4	Cell 1	Cell 5	Cell 6	Cell 2
	Median	1.5	1.8	1.2	1.2	0.81	0.50
vs. Cell 3	1.5	--					
vs. Cell 4	1.8	NS	--				
vs. Cell 1	1.2	NS	NS	--			
vs. Cell 5	1.2	NS	NS	NS	--		
vs. Cell 6	0.81	☆	NS	NS	NS	--	
vs. Cell 2	0.50	☆☆☆	☆	☆☆	☆	NS	--

NS: not significant ($p > 0.05$); ☆: $p \leq 0.05$; ☆☆: $p \leq 0.01$; ☆☆☆: $p \leq 0.001$. Cell 1: smoking household; Cell 2: nonsmoking household; Cell 3: smoking household/smoking workplace; Cell 4: smoking household/nonsmoking workplace; Cell 5: nonsmoking household/smoking workplace; Cell 6: nonsmoking household/nonsmoking workplace.

Table 11. Calculated 24-h exposures to RSP, ETS particles, and nicotine using median and 90th percentile air concentrations (Lisbon).

Cell[a]	RSP (μg)	ETS particles		
		SolPM (μg)	FPM (μg)	Nicotine (μg)
	Median levels			
1 (SH)	587	2.5	59	3.0
2 (NSH)	594	2.3	27	0.78
3 (SH, SW)	837	77	140	12
4 (SH, NSW)	873	152	191	10
5 (NSH, SW)	823	28	85	6.5
6 (NSH, NSW)	687	6.3	42	1.8
	90th percentile levels			
1 (SH)	1044	197	331	19
2 (NSH)	845	5.9	74	4.8
3 (SH, SW)	1409	491	470	58
4 (SH, NSW)	1111	290	354	42
5 (NSH, SW)	1749	454	510	43
6 (NSH, NSW)	974	75	221	17

[a] SH: smoking household; NSH: nonsmoking household; SW: smoking workplace; NSW: nonsmoking workplace.
NB A breathing rate of 0.65 $m^3 h^{-1}$ was assumed for housewives (Cells 1 - 2) and 0.85 $m^3 h^{-1}$ for working subjects (Cells 3 - 6).

for ETS particles were apparent. RSP, nicotine and ETS particle exposures during the monitoring period were also calculated using similar procedures according to the subjects' sex and are reported in Table 15. Irrespective of sex, and based on median calculated amounts, office workers in this study received more than double the daily exposure of ETS particles and nicotine than nonworkers. These median calculated amounts would also suggest a higher daily exposure for males than for females, irrespective of whether or not they are workers.

SUBJECTIVE COMPARISONS OF ETS EXPOSURE

As part of the last visit survey, subjects were asked a number of subjective questions regarding their exposure to ETS, both in general and during the 24-h monitoring period. The environments regarded by subjects as their single most exposed location to ETS are listed in Table 16. This table shows that 10 times as many people believe the workplace, rather than the home, to be the higher exposure location; however it also shows that restaurants/bars are generally perceived to contribute most to ETS exposure. The relatively high numbers considering outdoors or travelling to be their most exposed location may highlight subjects inability to differentiate between indoor and outdoor exposure levels, strengthening the hypothesis that good ventilation systems resulted in subjects in most indoor environments being exposed to similar "background" (outdoor) levels.

On their final visit to the study centre subjects were asked to rate their exposure to ETS, on a scale from none to very high, in a variety of locations, as reported in Figure 10. These results confirm that the locations with the highest perceived ETS exposures were bars/restaurants, where 35% of subjects assessed their exposures as high or very high. Similarly, high or very high exposures in the workplace were perceived by 16% of subjects and in the home by only 1% of subjects. A weighted average assessment of each location was made by assigning values from 0 (none) to 5 (very high) for each rating. This resulted in assessments in the range 0.64 to 2.38 with a ranking order of bars/restaurants > work > outdoors > other indoors > travelling > home.

CONCLUSIONS

Personal exposure levels to all analytes in this study suggested little difference between smoking and nonsmoking environments, probably due to the relatively low levels encountered resulting in the majority of

Table 12. Estimated annual exposures for all subjects to RSP, ETS particles, and nicotine, using calculated Cell concentrations (Lisbon).

	Annual exposure (mg)						
		ETS particles			Cigarette equivalents		
Cell[a]	RSP	SolPM	FPM	Nicotine	SolPM	FPM	Nicotine
	Median levels						
1 (SH)	214	0.91	22	1.1	0.08	2.0	1.4
2 (NSH)	217	0.85	9.7	0.28	0.08	0.88	0.35
3 (SH, SW)	306	9.4	43	2.6	0.85	3.9	3.3
4 (SH, NSW)	275	9.4	36	2.1	0.85	3.3	2.6
5 (NSH, SW)	220	4.9	19	1.5	0.45	1.7	1.9
6 (NSH, NSW)	236	2.2	15	0.70	0.20	1.4	0.88
All workers*	244	3.7	22	1.2	0.34	2.0	1.5
	90th percentile levels						
1 (SH)	381	72	121	7.1	6.5	11	8.9
2 (NSH)	309	2.2	27	1.8	0.20	2.5	2.3
3 (SH, SW)	606	172	176	21	16	16	26
4 (SH, NSW)	405	126	156	17	11	14	21
5 (NSH, SW)	513	98	109	9.9	8.9	9.9	12
6 (NSH, NSW)	381	19	70	4.6	1.7	6.4	5.8
All workers*	545	105	125	12	9.5	11	15

[a] SH: smoking household; NSH: nonsmoking household; SW: smoking workplace; NSW: nonsmoking workplace.

* "All workers": Cells 3 - 6 combined.

NB A breathing rate of 0.65 $m^3 h^{-1}$ was assumed for housewives (Cells 1 - 2) and annual exposures for each Cell were calculated by extrapolation of the median/90th percentile air concentrations to one year as follows:-

Annual exposure = median/90th percentile concentration x 0.65 x 24 x 365.

Median/90th percentile levels of ETS markers for workers at work and outside the workplace were calculated from the air concentrations provided by the "work" and "home" monitors in each Cell. A breathing rate of 0.85 $m^3 h^{-1}$ was assumed for working subjects (Cells 3 - 6) and annual exposures were calculated as follows assuming a 35-h working week and 48-week working year with the remainder of the time spent outside the workplace:-

median/90th percentile "work" concentration x 0.85 x 35 x 48

Annual exposure = +

median/90th percentile "home" concentration x 0.85 x ((24 x 365)-(35 x 48))

Table 13. Estimated contribution of the workplace to annual exposures of RSP, ETS particles, and nicotine for all working subjects (Lisbon).

		ETS particles		
Cell[a]	RSP	SolPM	FPM	Nicotine
	Median levels			
3 (SH, SW)	18%	28%	44%	45%
4 (SH, NSW)	32%	64%	50%	77%
5 (NSH, SW)	44%	70%	65%	72%
6 (NSH, NSW)	19%	36%	26%	31%
All workers*	27%	59%	50%	60%

(Table Continued)

Table 13. Continued.

	90th percentile levels			
3 (SH, SW)	29%	37%	29%	57%
4 (SH, NSW)	29%	48%	28%	11%
5 (NSH, SW)	39%	90%	77%	85%
6 (NSH, NSW)	25%	54%	45%	63%
All workers*	34%	65%	58%	67%

[a] SH: smoking household; NSH: nonsmoking household; SW: smoking workplace; NSW: nonsmoking workplace.
* "All workers": Cells 3 - 6 combined.

Table 14. Estimated annual exposures for all subjects to RSP, ETS particles, and nicotine, calculated on an individual basis (Lisbon).

	Annual exposure (mg)						
		ETS particles			Cigarette equivalents		
Cell[a]	RSP	SolPM	FPM	Nicotine	SolPM	FPM	Nicotine
	Median exposures						
1 (SH)	173	1.0	20	0.91	0.10	1.8	1.1
2 (NSH)	199	0.70	10	0.24	0.06	0.91	0.30
3 (SH, SW)	257	25	45	3.5	2.2	4.1	4.4
4 (SH, NSW)	292	38	63	2.5	3.5	5.7	3.1
5 (NSH, SW)	258	8.5	24	1.4	0.77	2.2	1.8
6 (NSH, NSW)	231	2.6	16	0.77	0.23	1.5	0.96
All workers*	257	8.7	29	1.5	0.79	2.6	1.9
	90th percentile exposures						
1 (SH)	400	65	104	8.3	5.9	9.4	10
2 (NSH)	361	1.7	31	2.1	0.16	2.8	2.7
3 (SH, SW)	688	148	140	15	13	13	19
4 (SH, NSW)	333	93	117	15	8.4	11	19
5 (NSH, SW)	514	106	107	11	9.6	9.8	14
6 (NSH, NSW)	352	21	68	4.5	1.9	6.2	5.6
All workers*	498	105	120	13	9.6	11	16

[a] SH: smoking household; NSH: nonsmoking household; SW: smoking workplace; NSW: nonsmoking workplace.
* "All workers": Cells 3 - 6 combined.
NB Breathing rates of 0.65 $m^3 h^{-1}$ for females and 1.05 $m^3 h^{-1}$ for males were assumed.
Annual exposures for individuals in Cells 1 - 2 were calculated by extrapolation of their calculated air concentrations to one year as follows:-

Individual annual exposure = air concentration x (0.65 or 1.05) x 24 x 365

ETS marker concentrations for workers at work and outside the workplace were calculated from the data provided by the "work" and "home" monitors. Annual exposures for individuals in Cells 3 - 6 were calculated as follows assuming a 35-h working week and 48-week working year with the remainder of the time spent outside the workplace:-

Individual annual exposure = *"work" concentration x (0.65 or 1.05) x 35 x 48* + *"home" concentration x (0.65 or 1.05) x ((24 x 365) - (35 x 48))*

Median and 90th percentile data were calculated for each cell from the individual exposures as determined above.

Table 15. Calculated median exposures to RSP, ETS particles, and nicotine during monitoring period (Lisbon).

Subject group	n	RSP (μg)	ETS particles		
			SolPM (μg)	FPM (μg)	Nicotine (μg)
All females	117	610	4.6	44	1.8
All males	80	935	12	98	5.6
Female housewives[a]	57	558	2.3	29	0.74
Female workers[b]	60	641	28	81	4.0
Male housewives[a]	23	1095	3.8	76	2.5
Male workers[b]	57	863	31	113	5.9

[a] Housewives refers to subjects recruited for Cells 1 and 2 (single monitor).
[b] Workers refers to subjects recruited for Cells 3 to 6 (dual monitor).
NB A breathing rate of 0.65 $m^3 h^{-1}$ was assumed for females and 1.05 $m^3 h^{-1}$ for males. The exposure time was that recorded on the monitors worn by each subject.

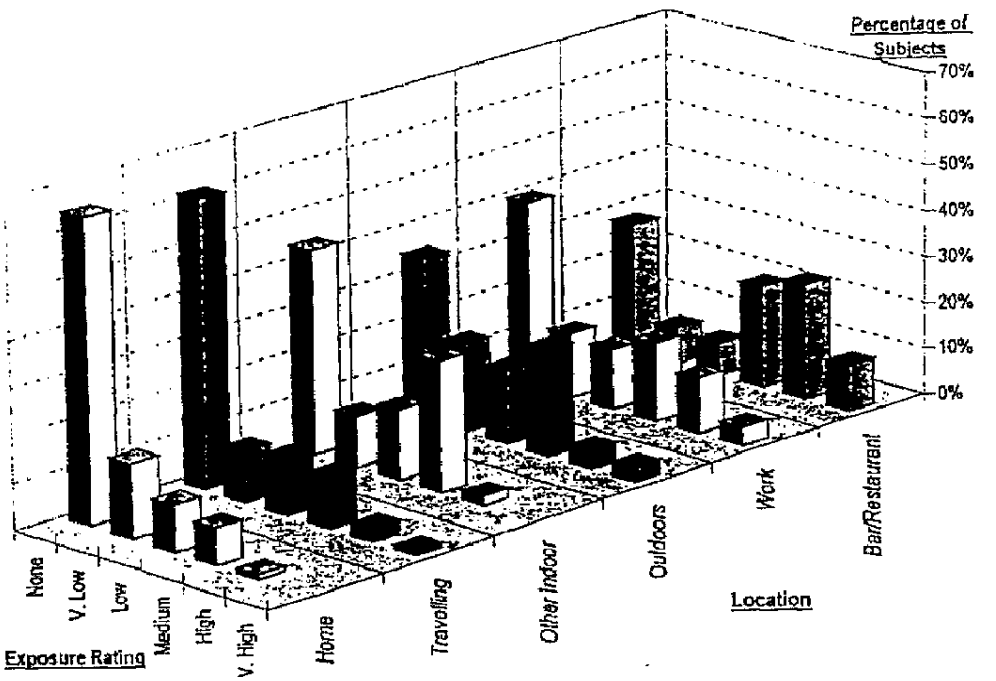

Fig. 10. Subjective ratings of exposure to ETS in various locations during the monitoring period (Lisbon).

results being below the LOQ. Median RSP levels of between 34 and 43 $\mu g\ m^{-3}$ were observed for the six Cells studied, but no significant differences were found between any of these Cells. These RSP concentrations probably reflect the background, outdoor levels and could suggest good ventilation systems in all indoor environments. No significant differences were observed between the ETS particle or nicotine concentrations found for workers, irrespective of their home/workplace smoking status, and housewives from smoking households. However, housewives living in nonsmoking households did encounter significantly lower levels of ETS particles (median SolPM 0.15 $\mu g\ m^{-3}$) and nicotine (median 0.05 $\mu g\ m^{-3}$) than any other subject groups in this study. These median concentrations for housewives from nonsmoking homes would equate to annual exposures of less than 0.4 CE.

Table 16. Subjective assessment of the environment where subjects considered themselves to be most exposed to ETS (Lisbon).

Environment	% of responses*
Restaurants/bars	39
Home	2.0
Outdoors	7.6
Travelling/driving	12
Work	21
Nowhere/not exposed	1.0

* Responses calculated as a percentage of total recruits, 34 subjects failed to answer this question correctly.

Extrapolation of daily concentrations to yearly exposure suggests that the workplace contributes most to overall ETS exposures, with environments outside of the workplace contributing most to RSP for the majority of subjects in this study. Based on upper decile levels for ETS particles and nicotine, the most highly exposed workers from smoking households and offices would be exposed to the equivalent of between 13 and 19 CE/y.

The rate at which self-reported nonsmokers misclassified their smoking status in this study ranged between 17.5% and 18.3%, dependent upon the criteria used, and were the highest rates observed in the European cities studied to date. However, the fact that initial contact for recruitment in Lisbon was performed using a letter which mentioned the payment of a gratuity, a method used only for this city, may have influenced subjects to misreport their smoking status.

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